PS04 Berry's phase in the multimode Peierls states(Topological Aspects of Solid State Physics)

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Topology of exciton in artificial structure

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Topology of an electron wavefunction in artificial structures are determined by the structural parameters if the disturbance of the electron can be neglected. The topology of an exciton wavefunction, however, heavily depends on the delocalized feature of the relative motion of an electron-hole pair making an exciton as well as the structural parameters. We focused our eyes to this situation and have investigated the topological aspects of the exciton in nanotube structure theoretically.

By employing a variational method, we have calculated the excitonic properties of thin nanotube structures. The exciton wavefunctions show variety of spatial distribution patterns depending on the structural parameters of the nanotube structure. We found that the change of the exciton wavefunction by controlling the tube circumference length is strongly related to the topology of the wavefunction. The kinetic energy of the ground state exciton in nanotubes decreases monotonically when the circumference length decreased. This is a curious behavior because smaller confinement region yields larger confinement kinetic energy in conventional artificial structures. The exciton wavefunction is delocalized and connected in the case that the circumference of nanotube is small, while the exciton wavefunction is localized for large circumference nanotube. The connected wavefunction has ring-like topology and it yields the constant like wavefunction for the ground state electron and hole reducing the confinement energy of the exciton.

We have also found that the topological transition can be controlled even by changing the barrier dielectric constant of the nanotubes. This implies that we can control the topology of the exciton wavefunction simply by changing the dielectric constant or other material parameters. We expect the control of the artificial structure providing a novel guiding principle for creating functional devices through the topological control of excitons.

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Berry's phase in the multimode Peierls states

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Quantized Berry's phase associated with the adiabatic change of local variables [1] is shown to be useful in the characterization of the multimode Peierls state which has been proposed as a new type of the ground state of two-dimensional systems with the electron-lattice interaction [2]. The conventional Peierls state in two dimension is characterized by one Fourier mode, namely the (π, π) mode, whereas the multimode Peierls states exhibit complicated lattice distortion patterns with more than one Fourier modes. We show that there exists one to one correspondence between the quantized value of Berry's phase and the sign of lattice distortions in the multimode Peierls states [3]. Quantized Berry's phase can therefore be used to characterize the complicated distortion patterns in the multimode Peierls states. This topological characterization in real space reveals the topological stability of the multimode Peierls states and is useful in analyzing the phase transitions between the multimode Peierls states and the conventional Peierls state in the presence of anisotropy [4].

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